Tropical upwelling and sea surface temperatures

Rudolf Deckert, Hella Garny, Theresa Runde

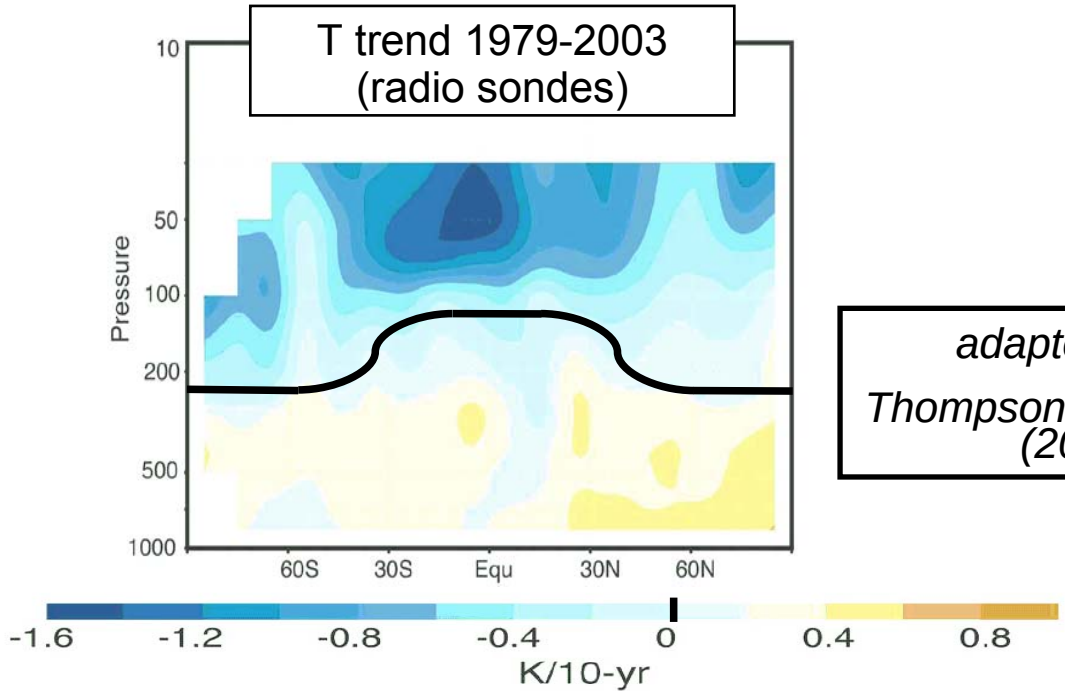
Martin Dameris, Sigrun Matthes

German Aerospace Center

Institute of Atmospheric Physics

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Introduction



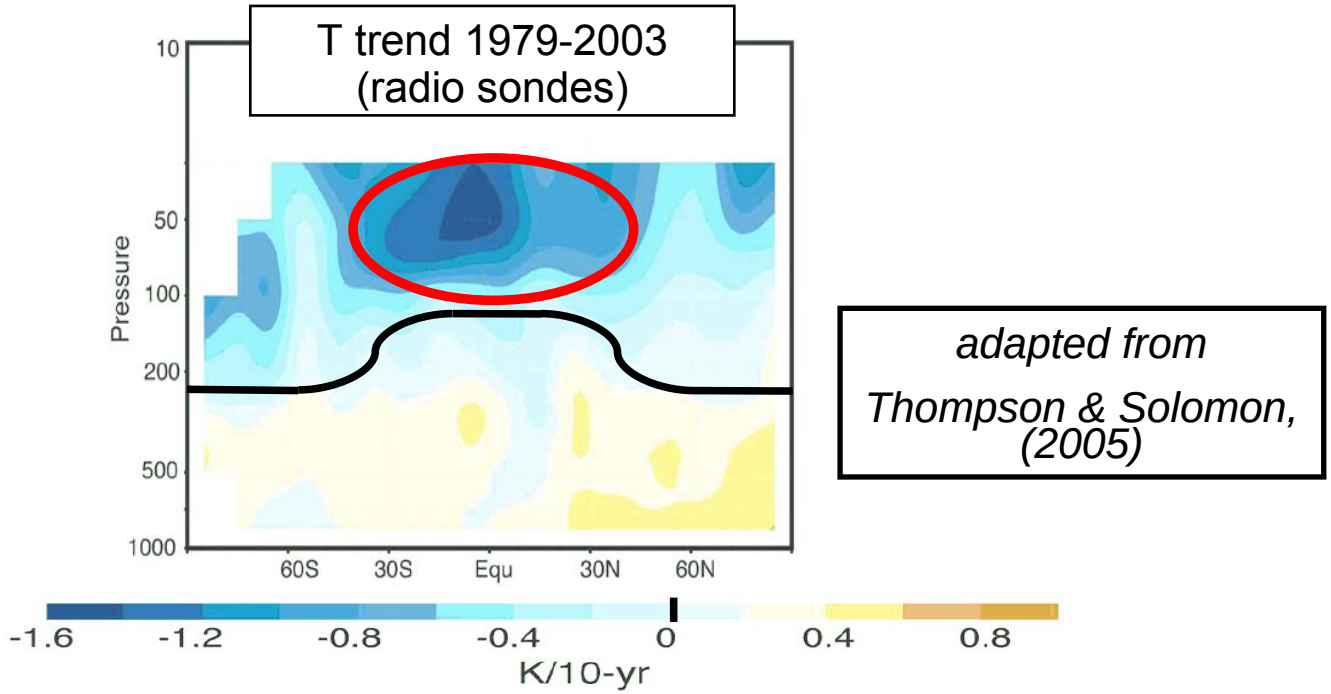
adapted from

Thompson & Solomon, (2005)

Introduction

Tropical lower stratosphere: indications of local

- max. cooling *(see also Fu et al., 2010)*
- max. ozone decrease *(e.g. Randel et al., 2006)*

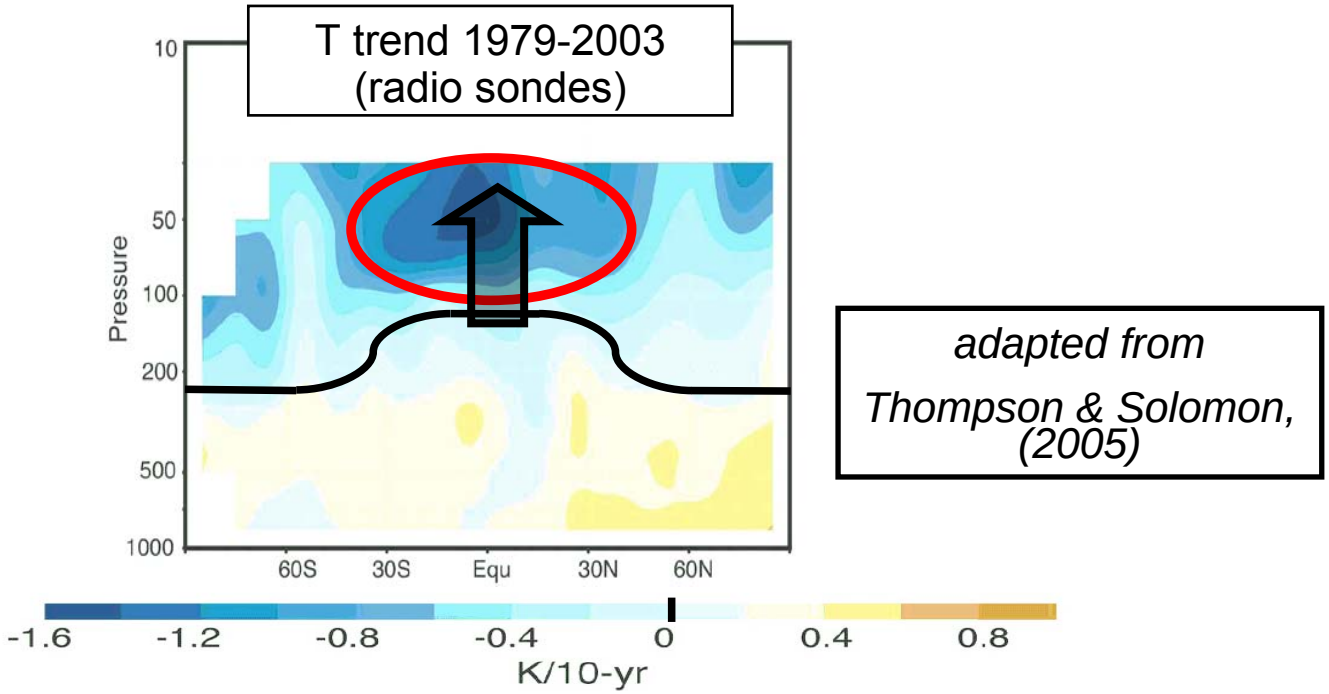


Introduction

Tropical lower stratosphere: indications of local

- max. cooling *(see also Fu et al., 2010)*
- max. ozone decrease *(e.g. Randel et al., 2006)*

⟶ Hypothesis: stronger tropical upwelling



Introduction

Hypothesis backed up by most chemistry-climate models (CCMs)

(e.g. Butchart et al., 2006, 2010)

… also by our CCM E39C

(Deckert and Dameris, 2008; Garny et al., 2009, 2011; Runde et al., in prep.)

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- Higher sea surface temperatures (SSTs) ⟶ stronger tropical upwelling
- Mediation via enhanced wave dissipation

  (e.g. Sigmond et al., 2004; Fomichev et al., 2007; Oman et al., 2009; Garny et al., 2011)

Introduction

Stronger wave dissipation

What mechanisms?

Here:

Dissipation of stationary waves
in tropical lower stratosphere

Mechanisms

Wave production

1. More convective excitation *(Deckert and Dameris, 2008)*

Wave propagation (background state)

2. More focusing towards equator *(Garcia and Randel, 2008)*

Wave dissipation (background state)

3. Less dissipation in troposphere *(Garny et al., 2011)*

Mechanisms

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Show our E39C results from studies 1 and 3 to

- demonstrate mechanisms
- investigate differences

Simulations with our CCM E39C

„globe“
(Deckert and Dameris, 2008)

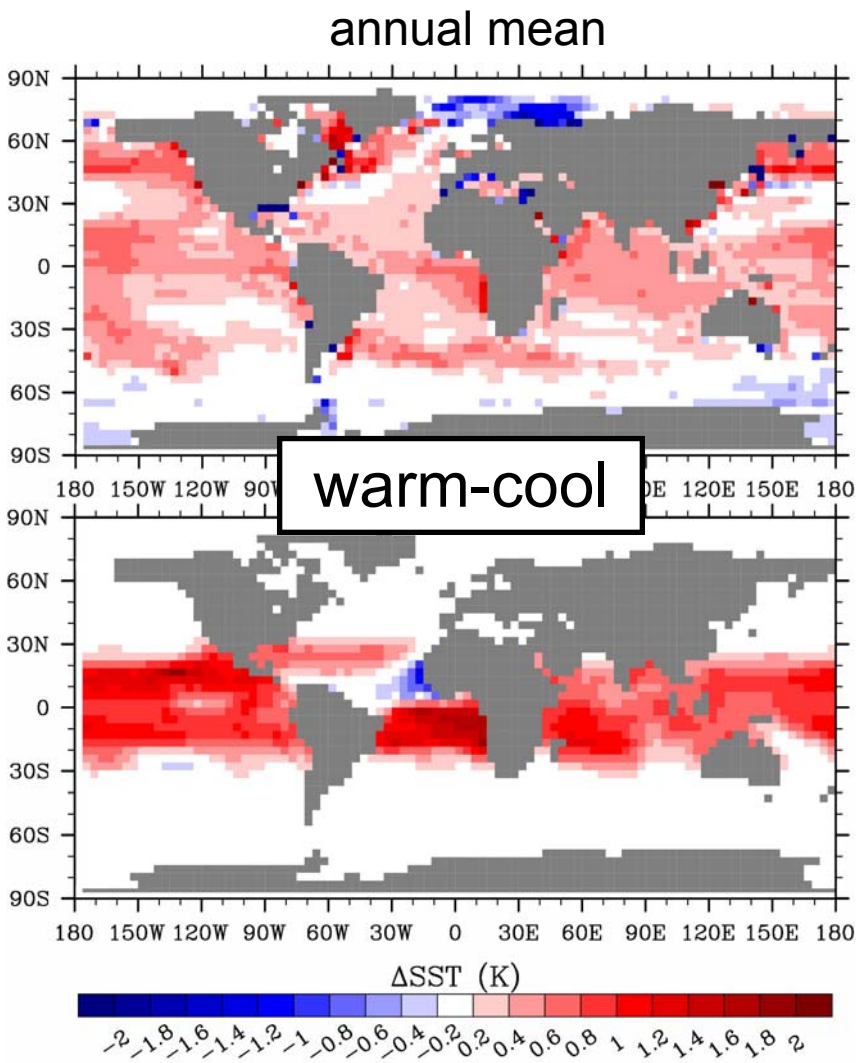
1. Warm: model SSTs
2. Cool: obs. SSTs

➢ GHGs differ

„tropics“
(Garny et al., 2011)

1. Warm: model SSTs + anomaly
2. Cool: model SSTs

➢ GHGs identical



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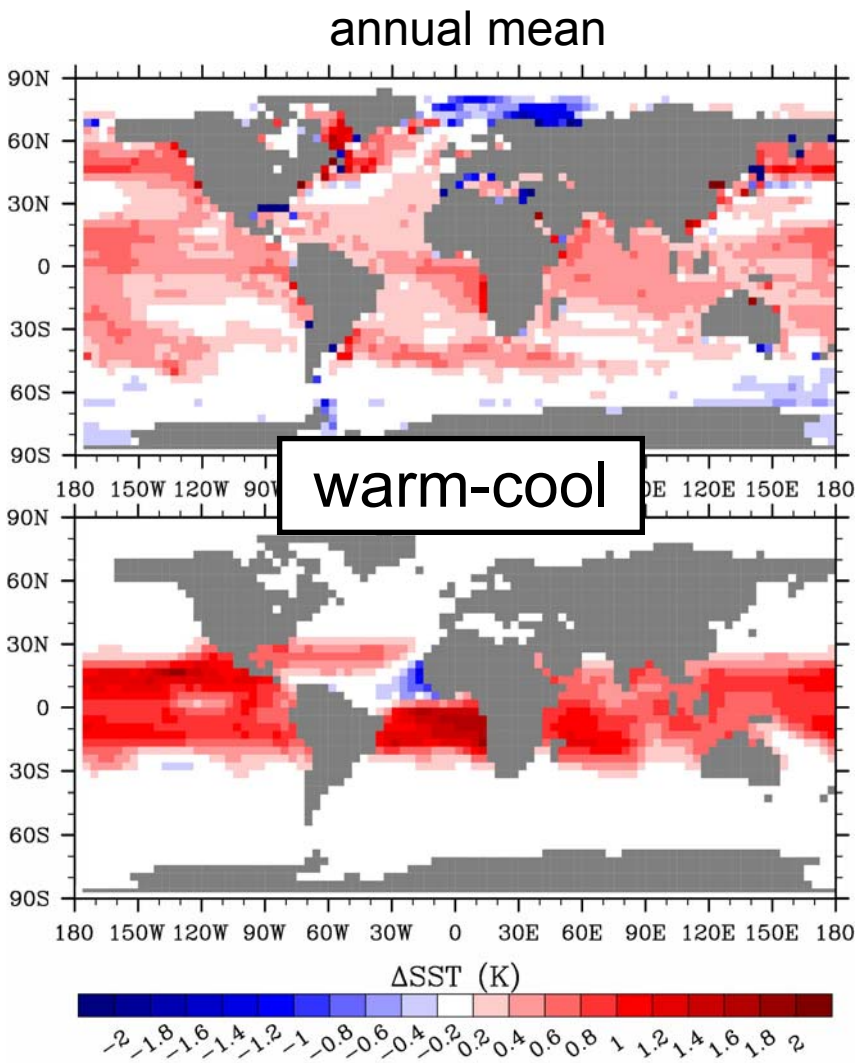
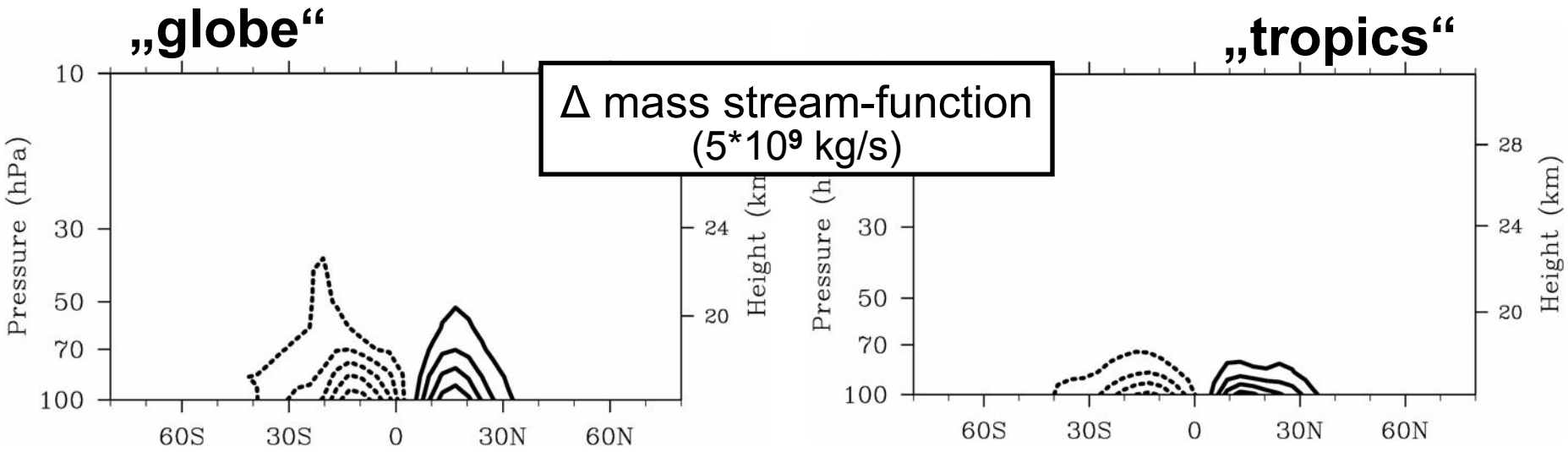
anomaly warm-cool …



Annual mean


„globe“
„tropics“
Δ mass stream-function
(5*10⁹ kg/s)
Pressure (hPa)
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60S
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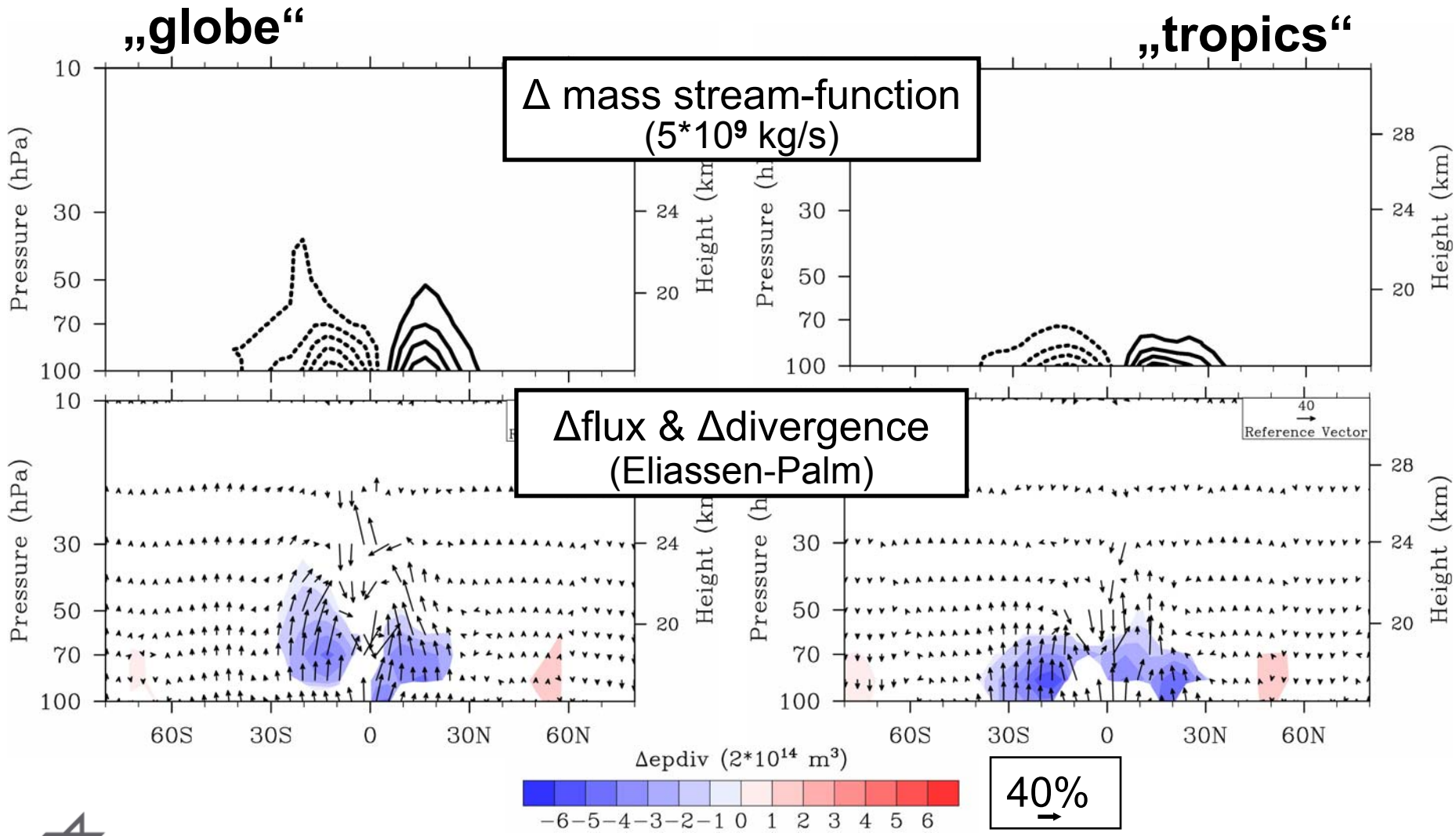
30N
60N
Height (km)
24
20
28

Annual mean


„globe“
„tropics“
Δ mass stream-function
(5*10⁹ kg/s)
Δflux & Δdivergence
(Eliassen-Palm)
Pressure (hPa)
Height (km)
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100
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30S
0
30N
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Reference Vector
Δepdiv (2*10¹⁴ m³)
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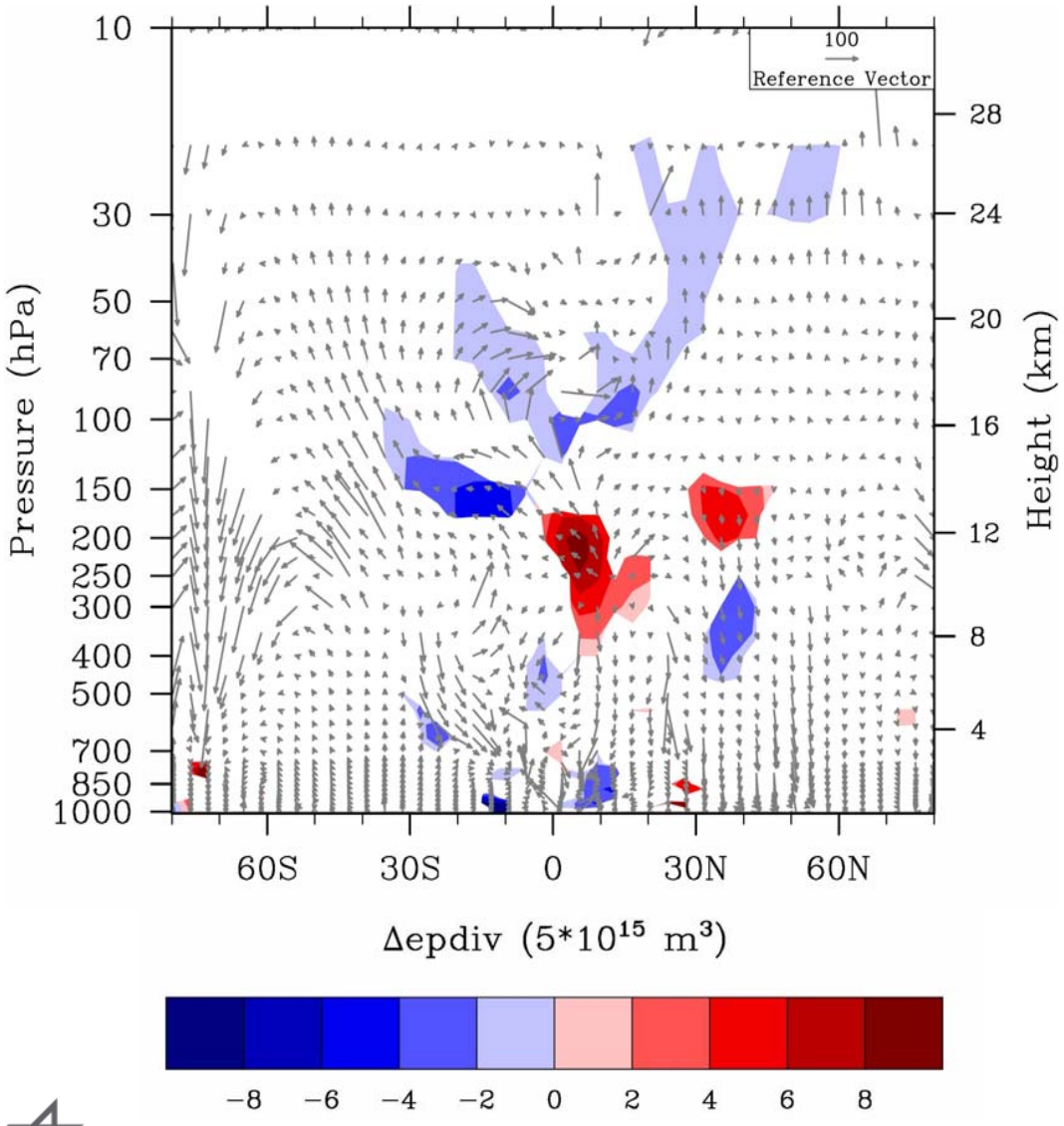
40%

JJA: „globe“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Δepdiv (5*10^15 m^3)
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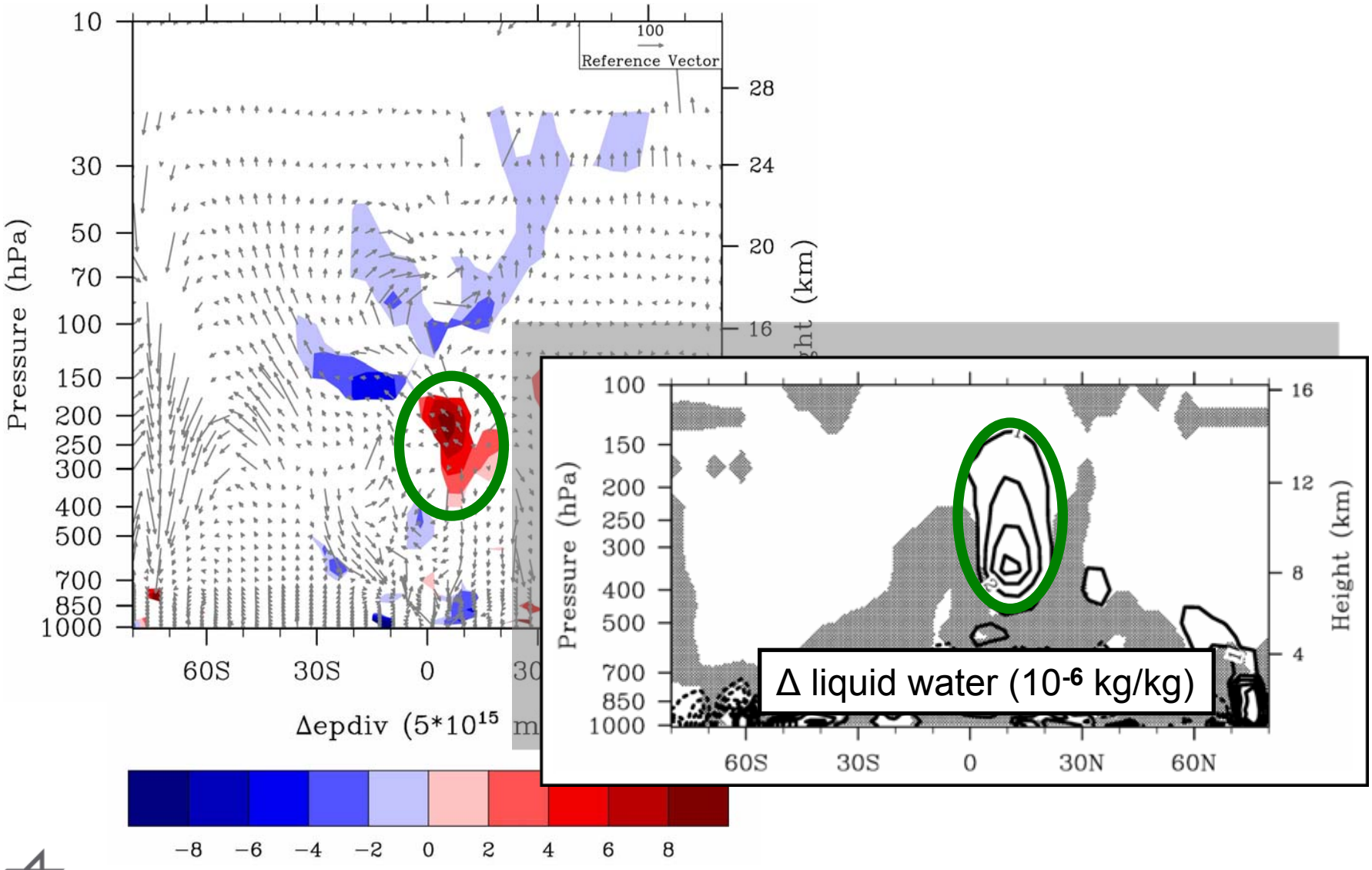
8

JJA: „globe“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30S
0
Δepdiv (5*10^15
−8 −6 −4 −2 0 2 4 6 8
Pressure (hPa)
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700
850
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12
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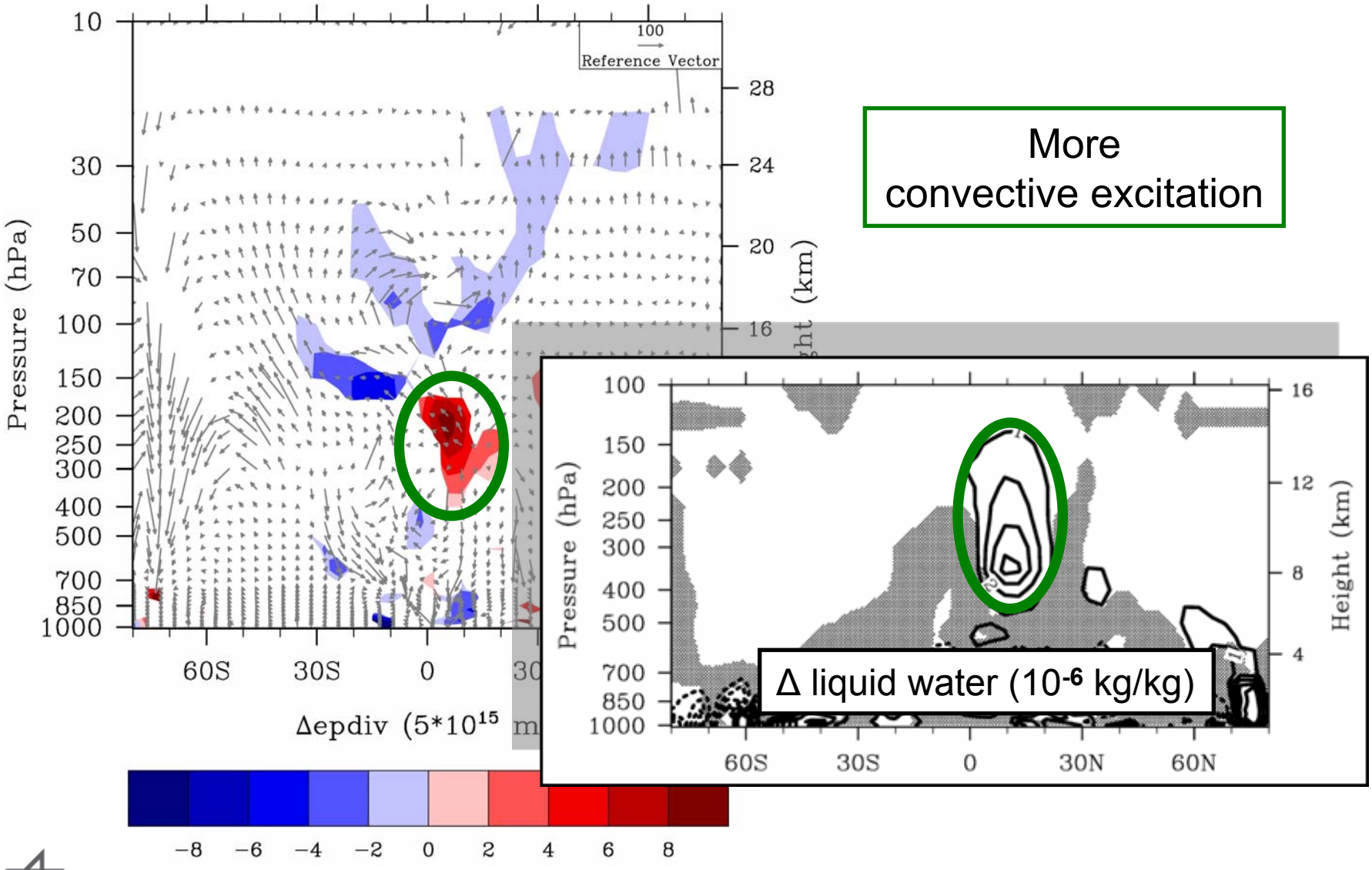
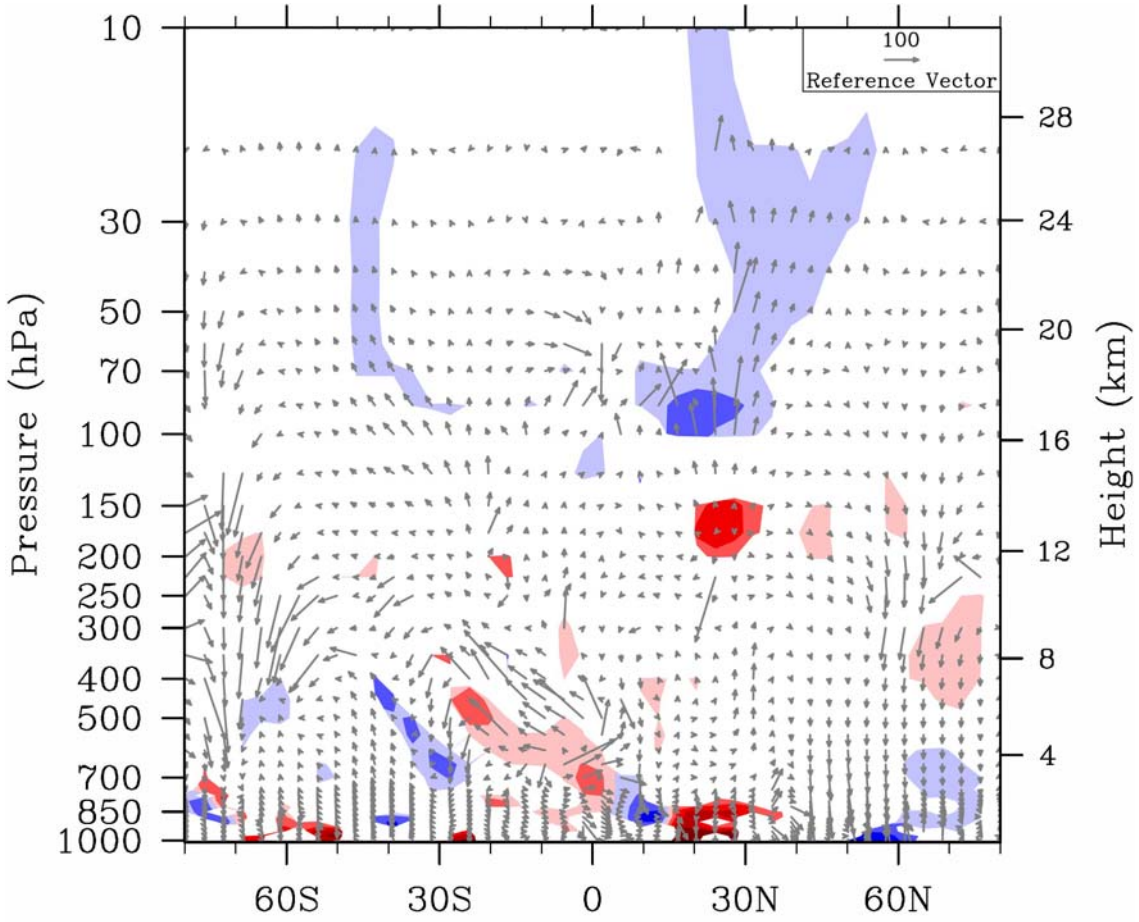
4
Height (km)
60S
30S
0
30N
60N
Δ liquid water (10-6 kg/kg)

JJA: „globe“



More
convective excitation

JJA: „tropics“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Reference Vector
Pressure (hPa)
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Height (km)
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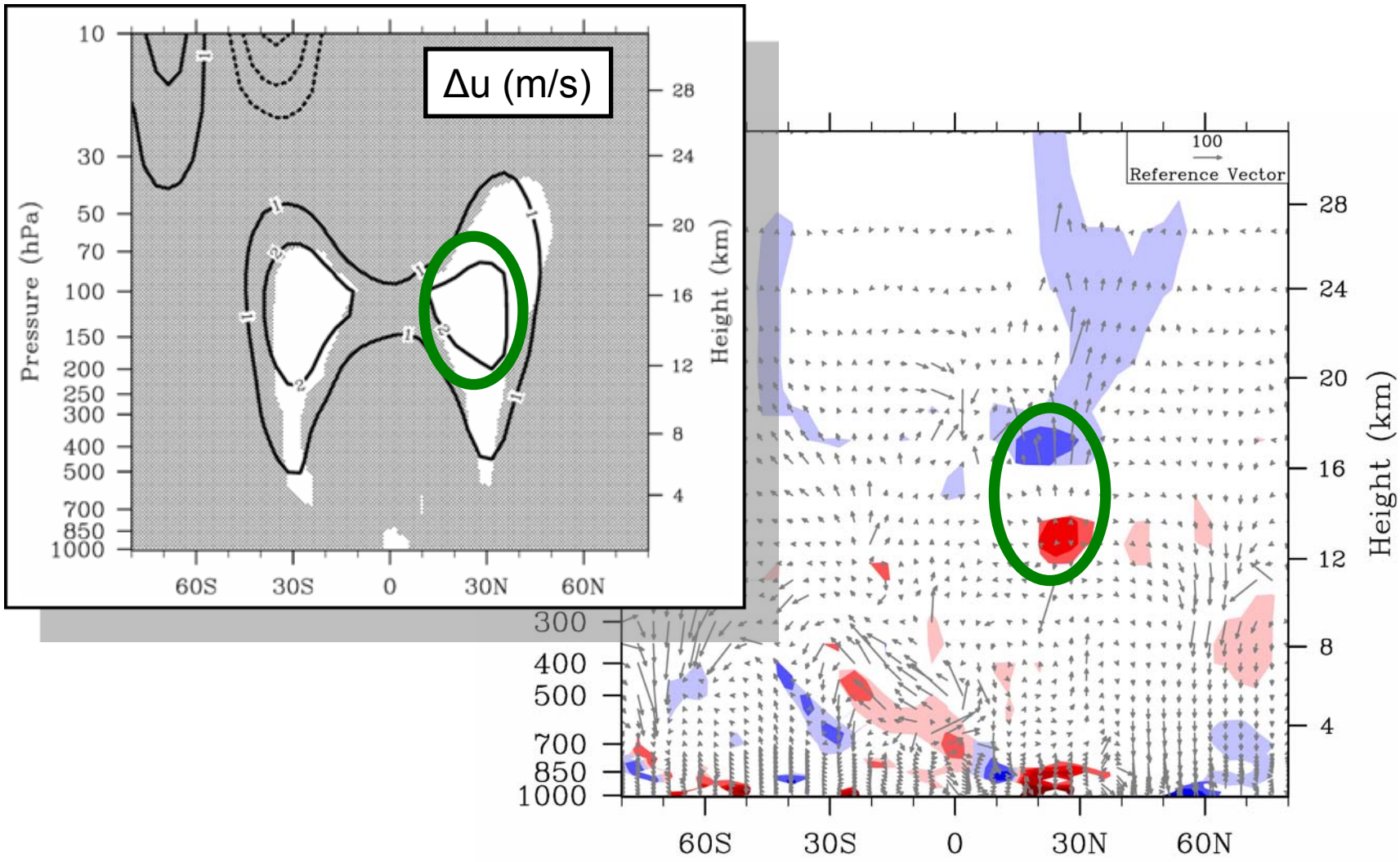
30N
60N

JJA: „tropics“


Δu (m/s)
Pressure (hPa)
Height (km)
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250
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700
850
1000
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16
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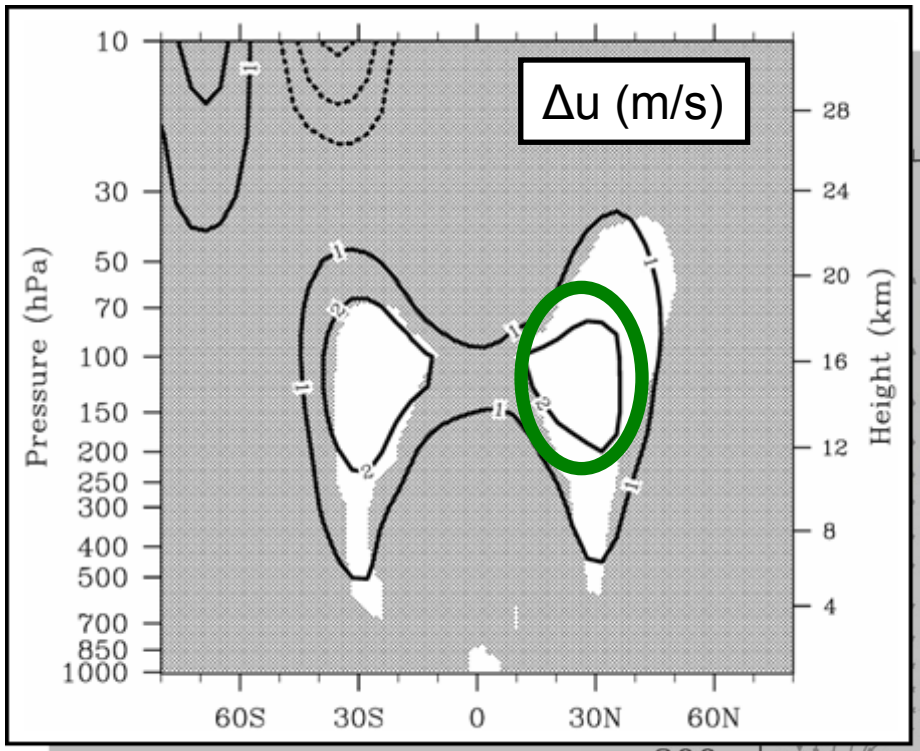
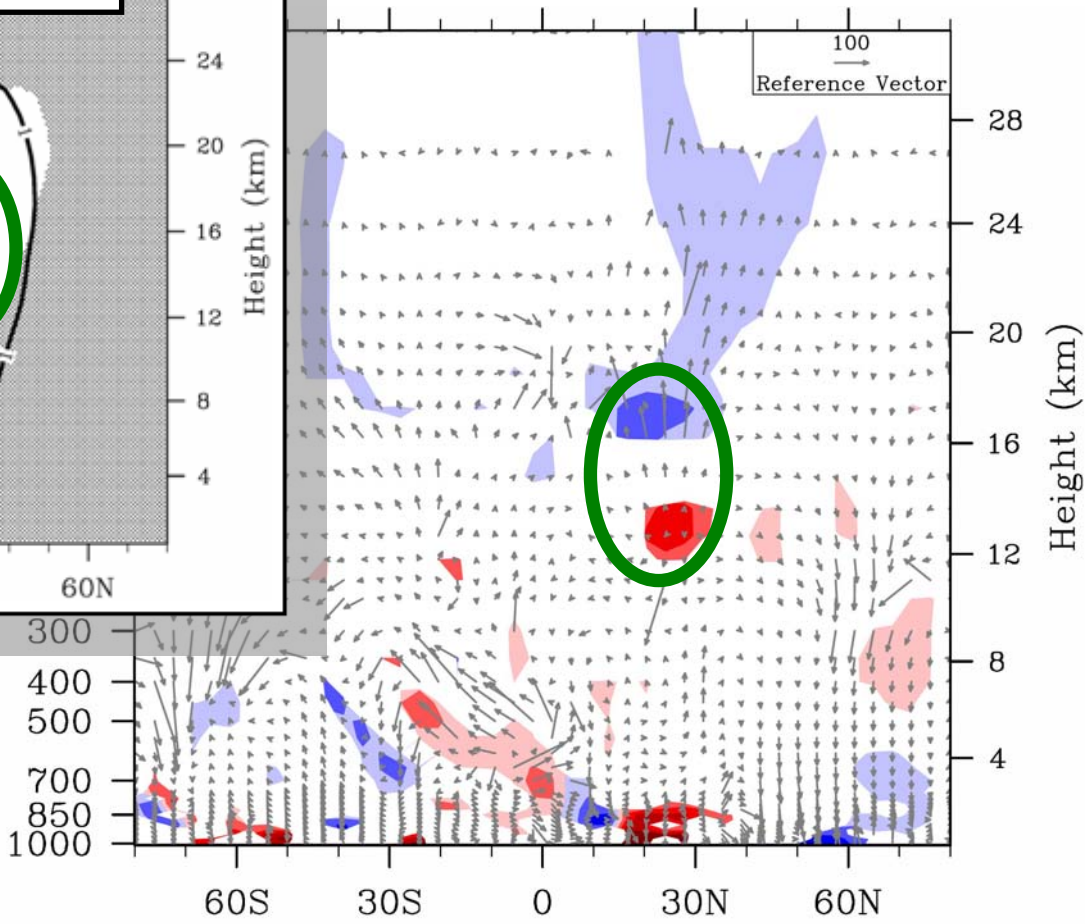
8
4
60S
30S
0
30N
60N
100
Reference Vector

JJA: „tropics“





Less dissipation
in troposphere

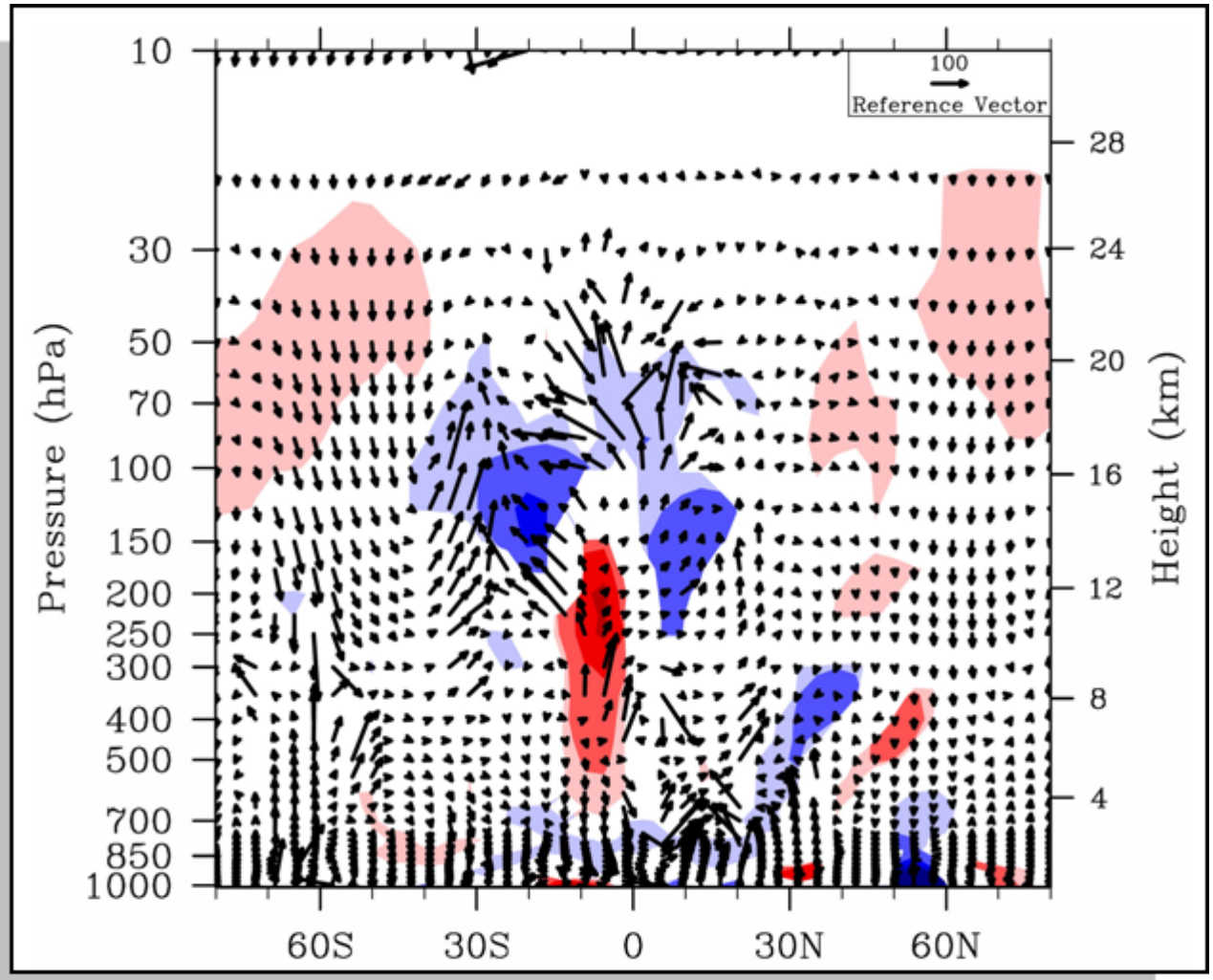
DJF: „globe“ & „tropics“

Inconclusive results for DJF

→ Fourier decomposition

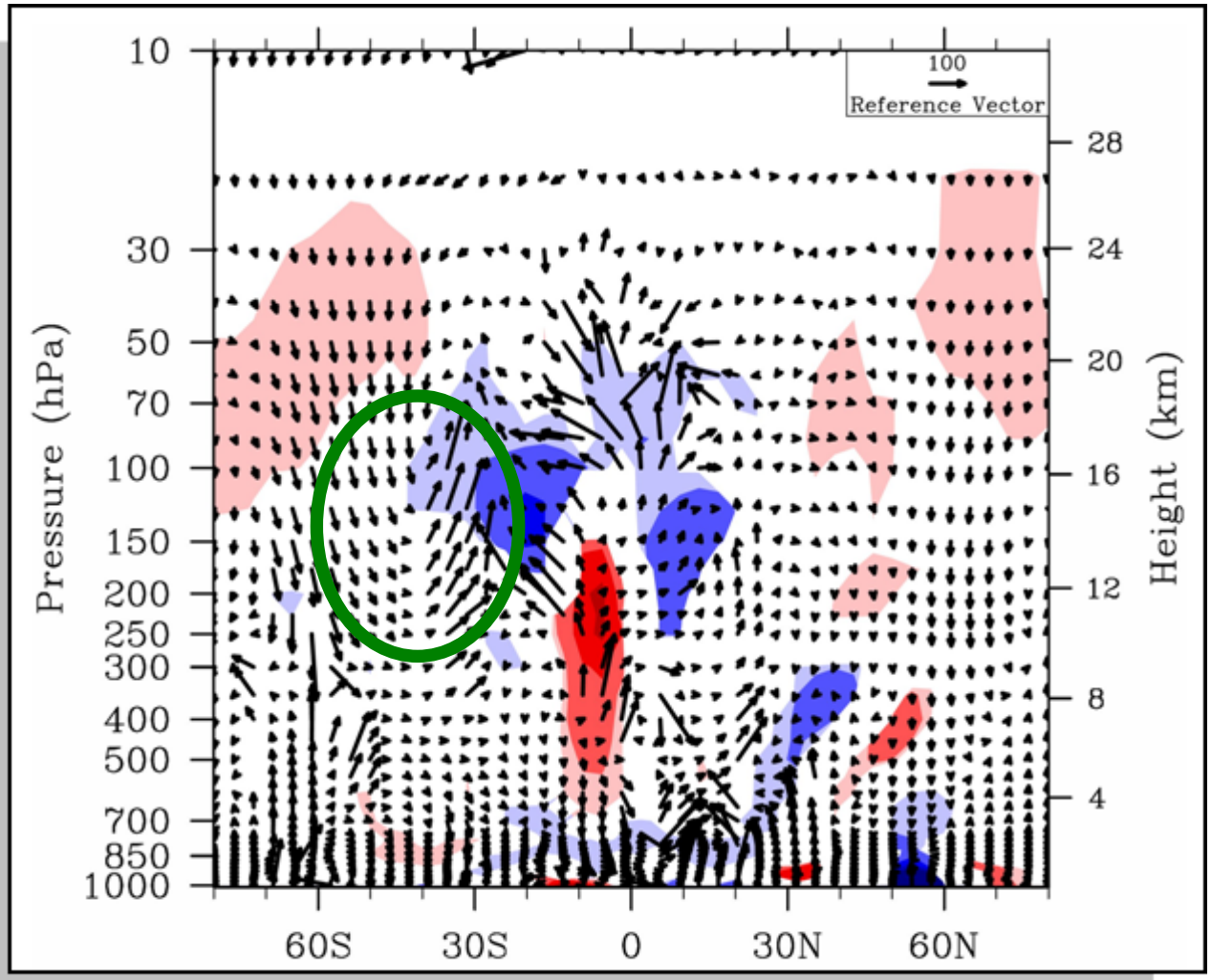
DJF: wave 1

„tropics“



DJF: wave 1

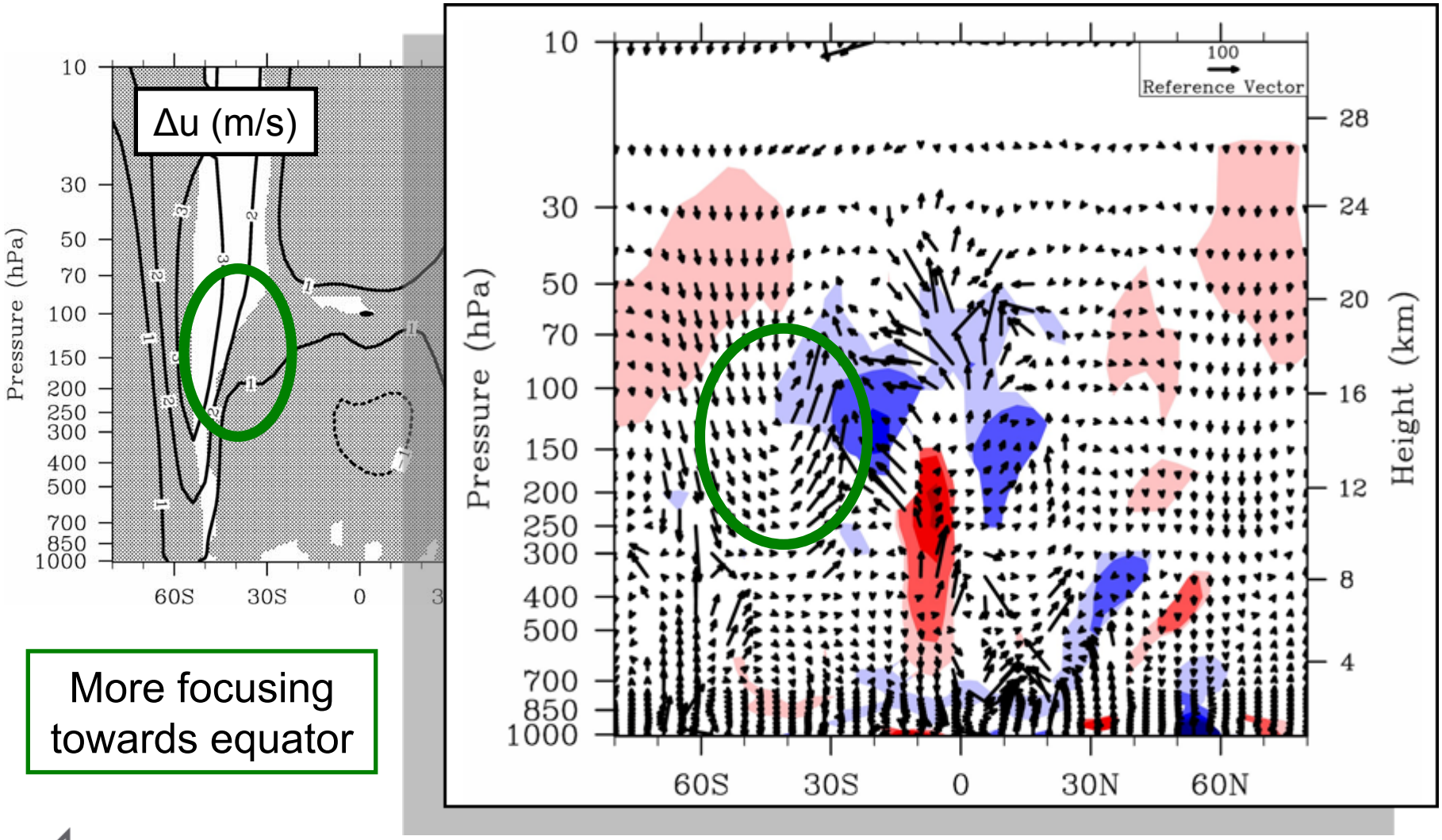
„tropics“



More focusing towards equator

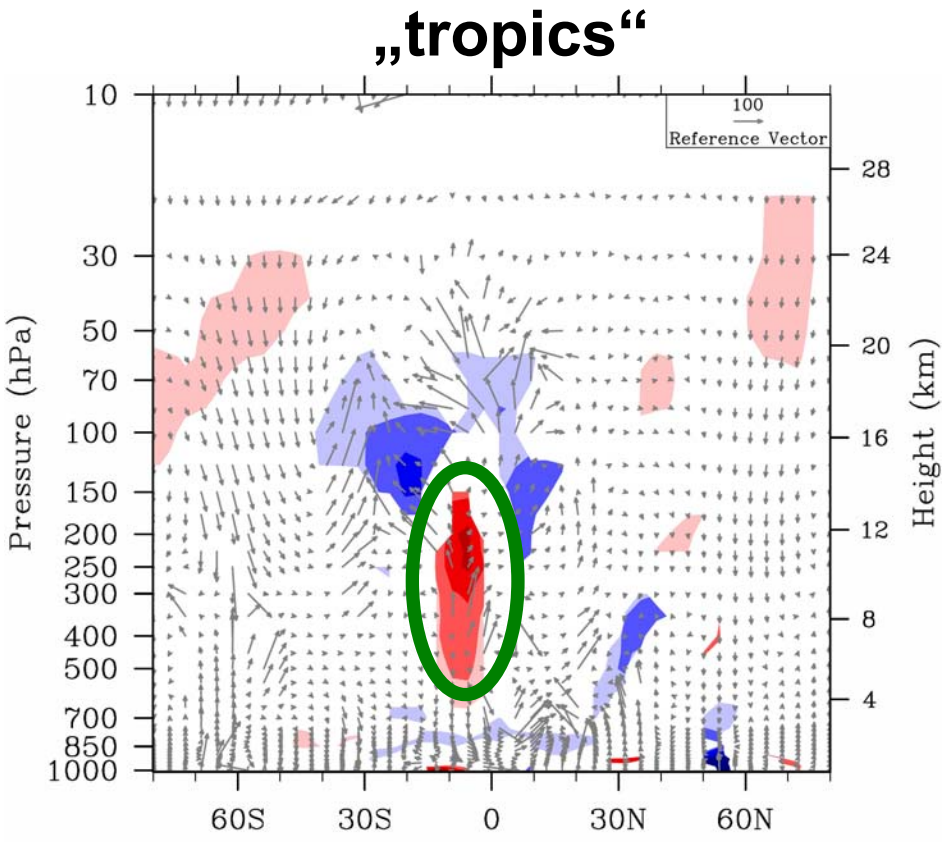
DJF: wave 1

„tropics“



More focusing towards equator

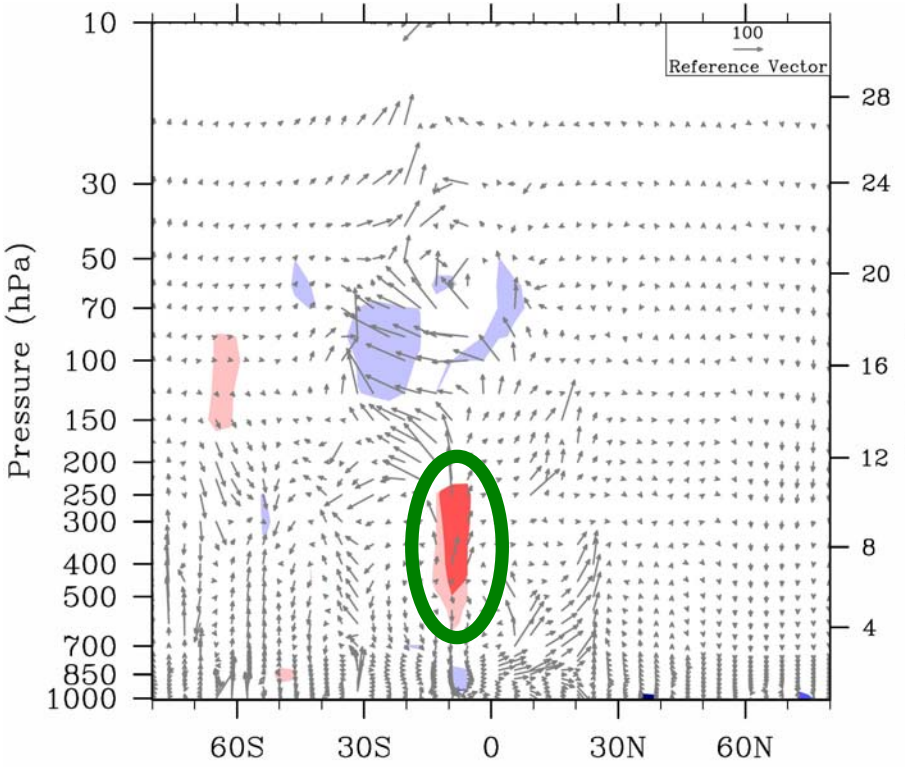
DJF: wave 1



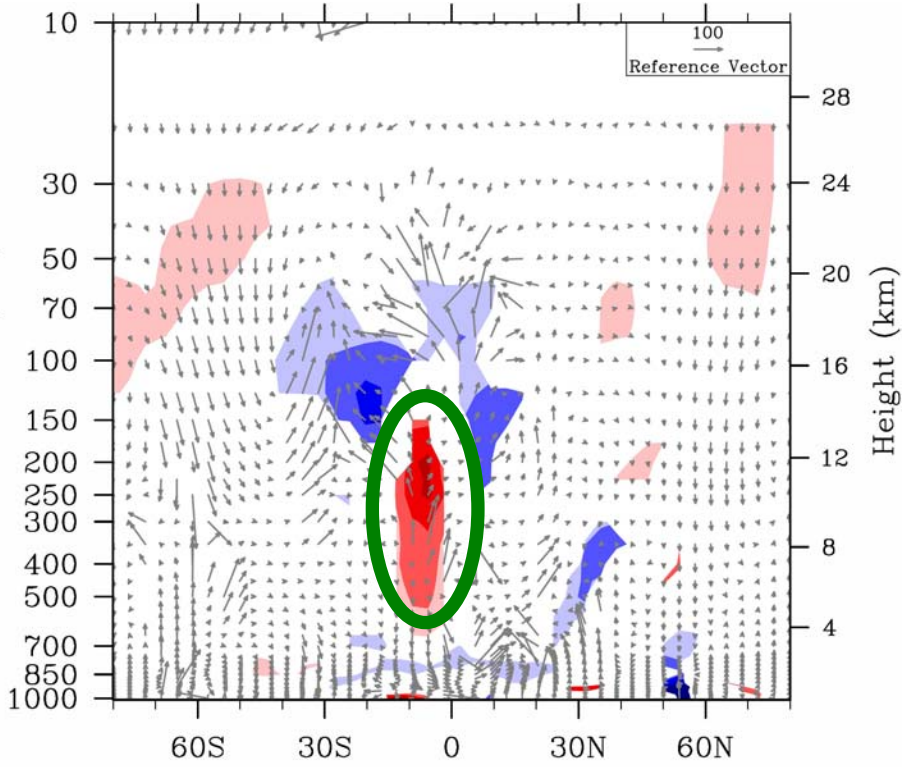
More
convective excitation

DJF: wave 1

„globe“



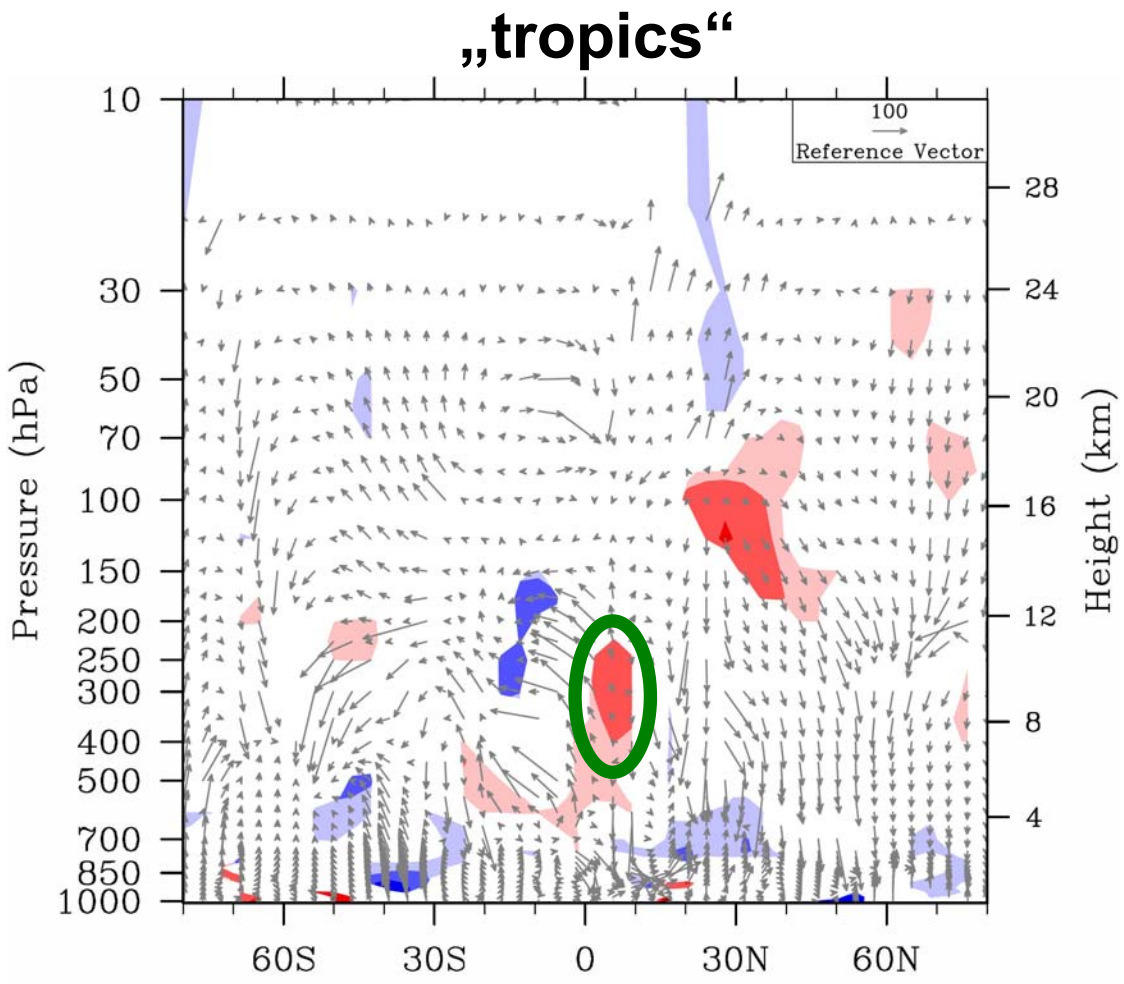
„tropics“



More
convective excitation

JJA: waves 2 & 3

More
convective excitation



Conclusions

Most CCMs reveal for warmer climate

- Stronger tropical upwelling
- Importance of SSTs
- Mediation via enhanced wave dissipation

} Here: stationary waves in tropical lower stratosphere

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stationary waves in tropical lower stratosphere

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- More convective excitation
- Stronger focusing towards equator
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Mechanisms depend on

- Scenario details: mainly SST patterns, also GHGs
- Season
- Wave number

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Mechanisms depend on

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Brewer-Dobson circulation may be unaffected!

(e.g. Engel et al., 2008)

Sensitivities

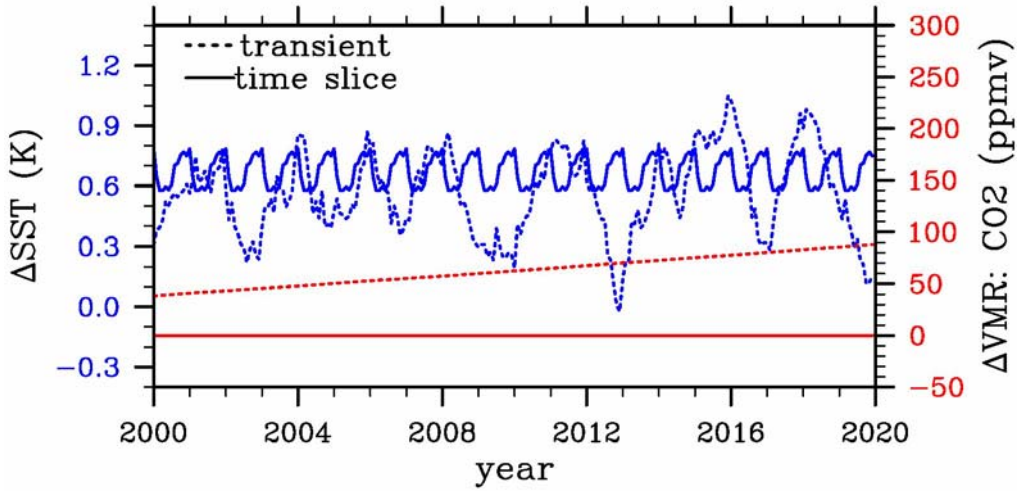
Transient sensitivity *(Deckert and Dameris, 2008)*

1. Warm: IPCC A1b, model SSTs for 2000-2019 (HADGEM1)
2. Cool: GHGs for year 1980, observed SSTs for 1970-1979

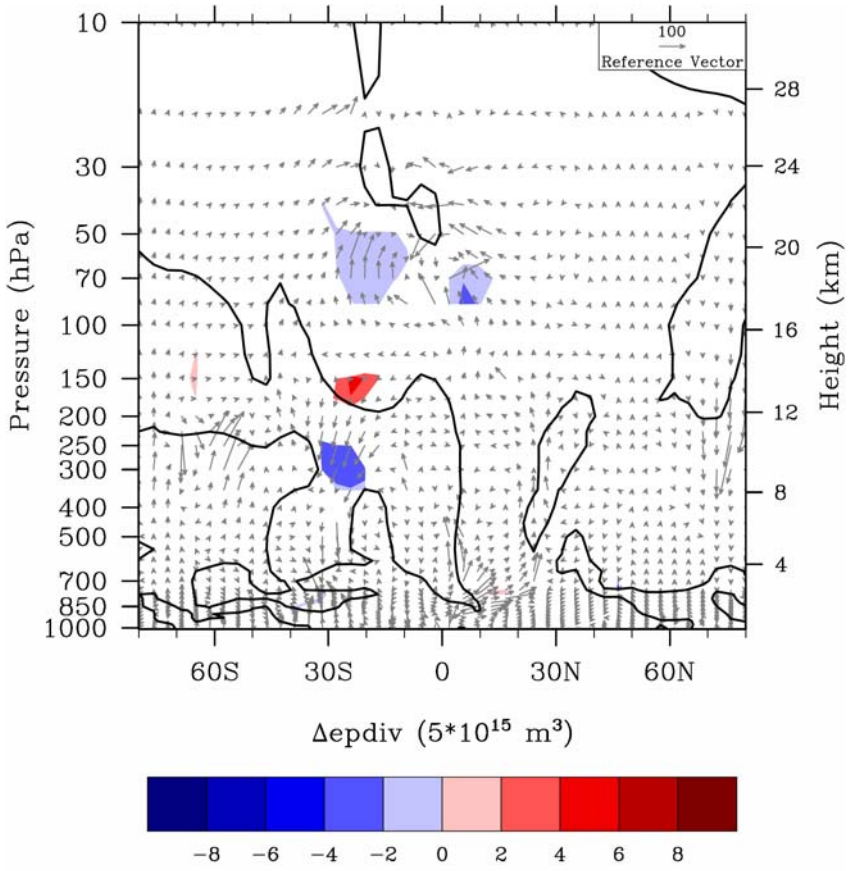
Time-slice sensitivity *(Garny et al., 2011)*

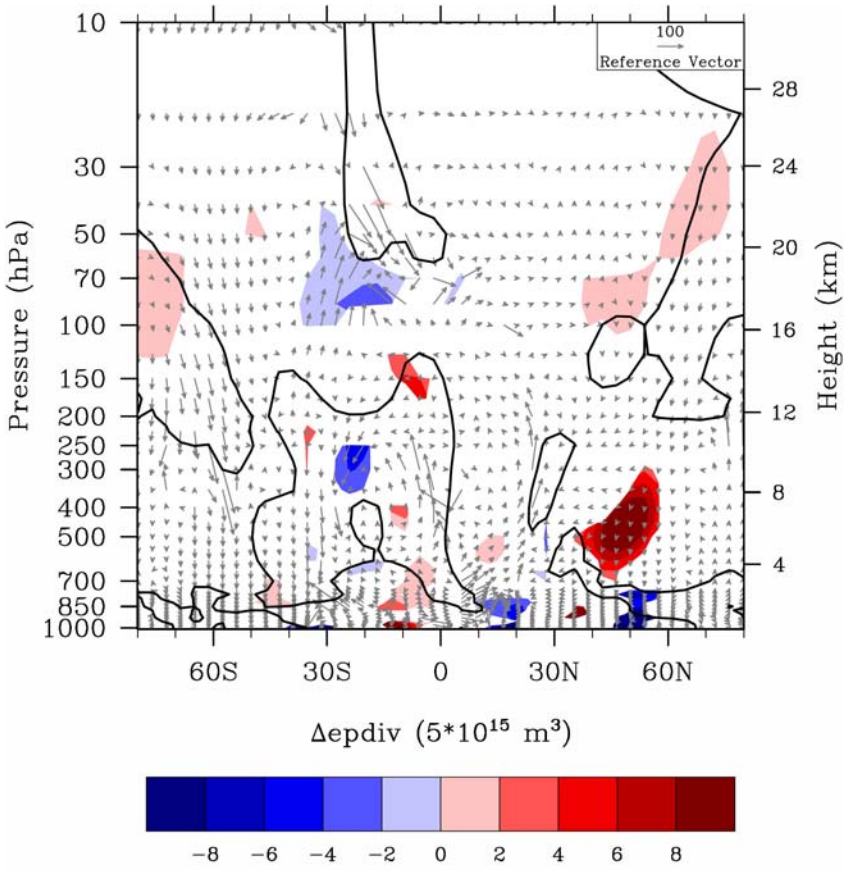
1. Warm: as cool, but higher SSTs between 30°N-30°S
2. Cool: model SSTs (HADGEM1) for average 1995-2004

➢ Identical GHGs for year 2000

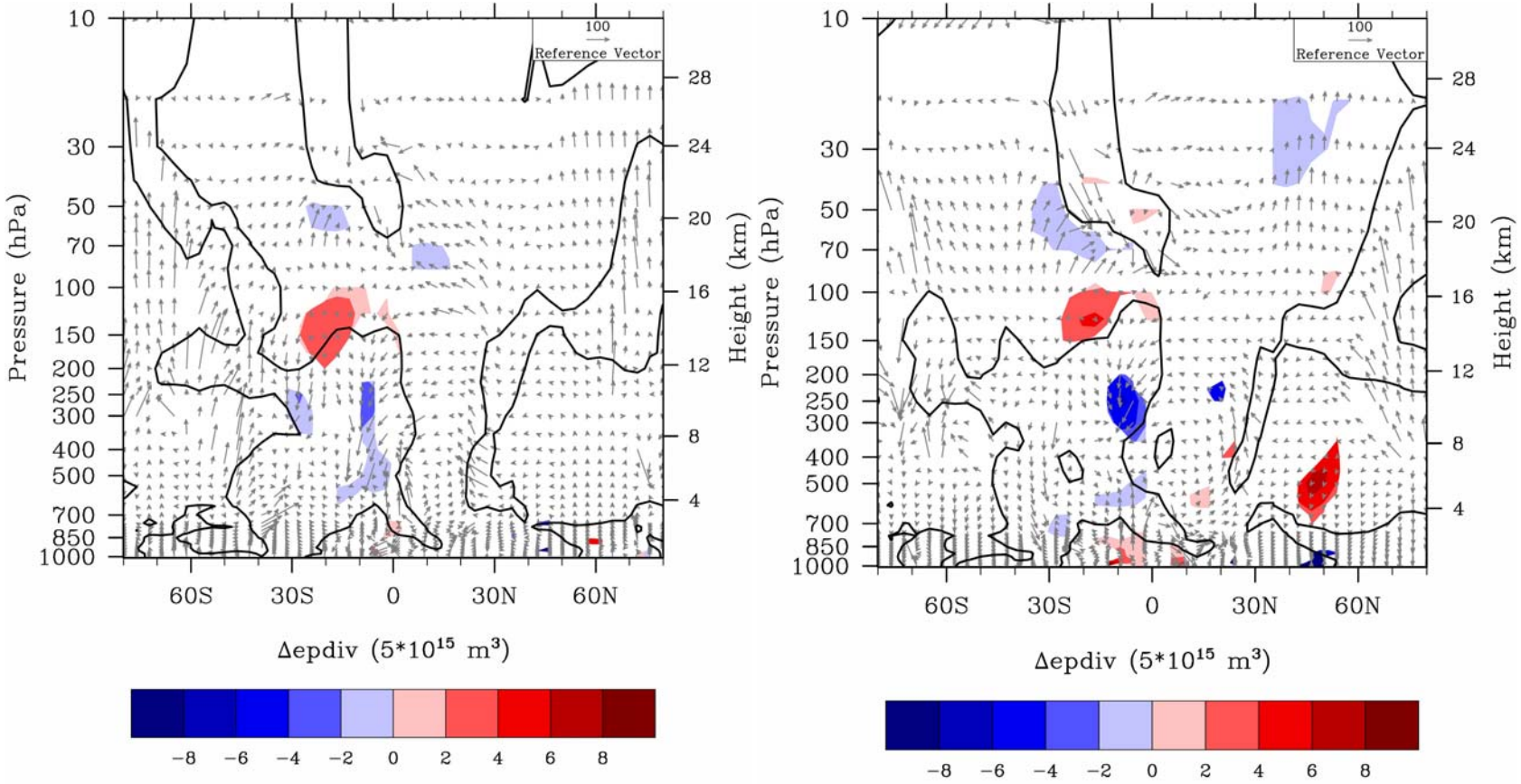


DJF: all waves





DJF: waves 2 & 3


Pressure (hPa)
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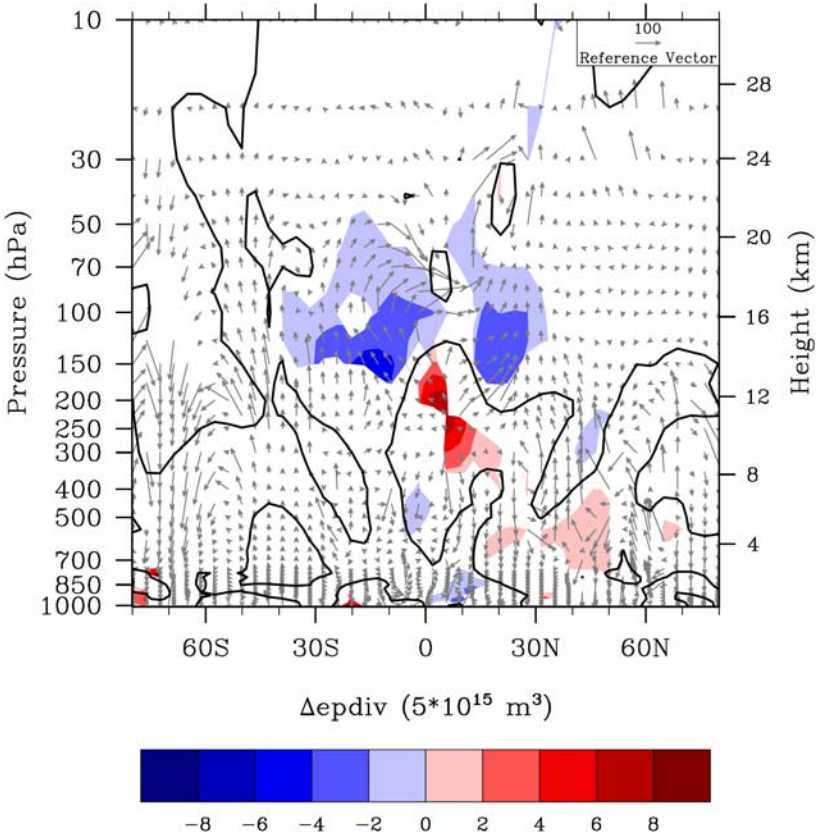
Δepdiv (5*10¹⁵ m³)
−8 −6 −4 −2 0 2 4 6 8

JJA: wave 1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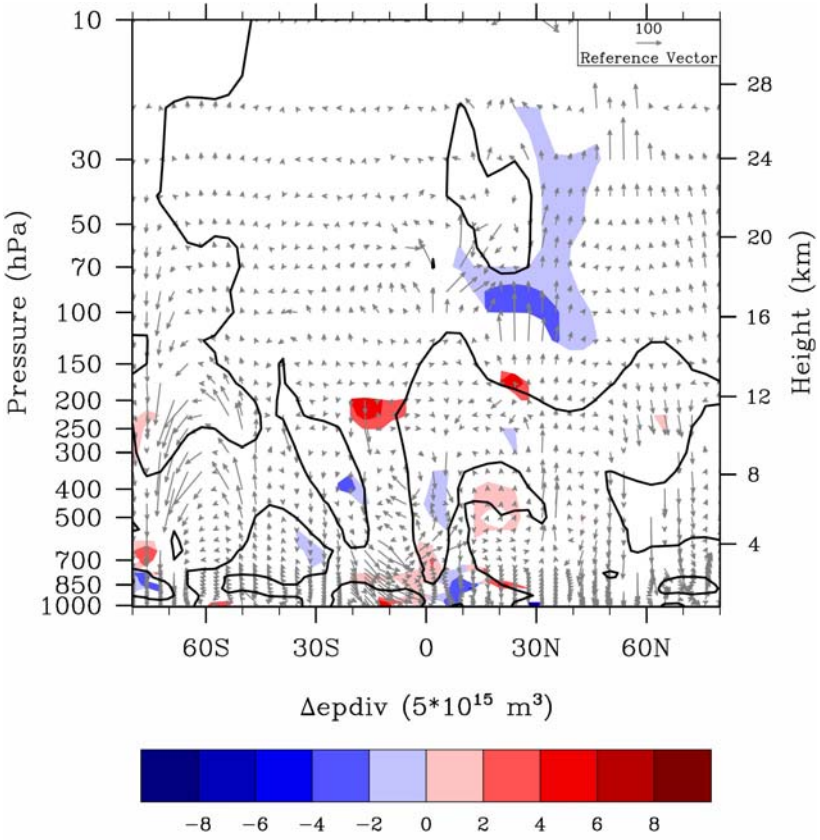
Δepdiv (5*10¹⁵ m³)
−8 −6 −4 −2 0 2 4 6 8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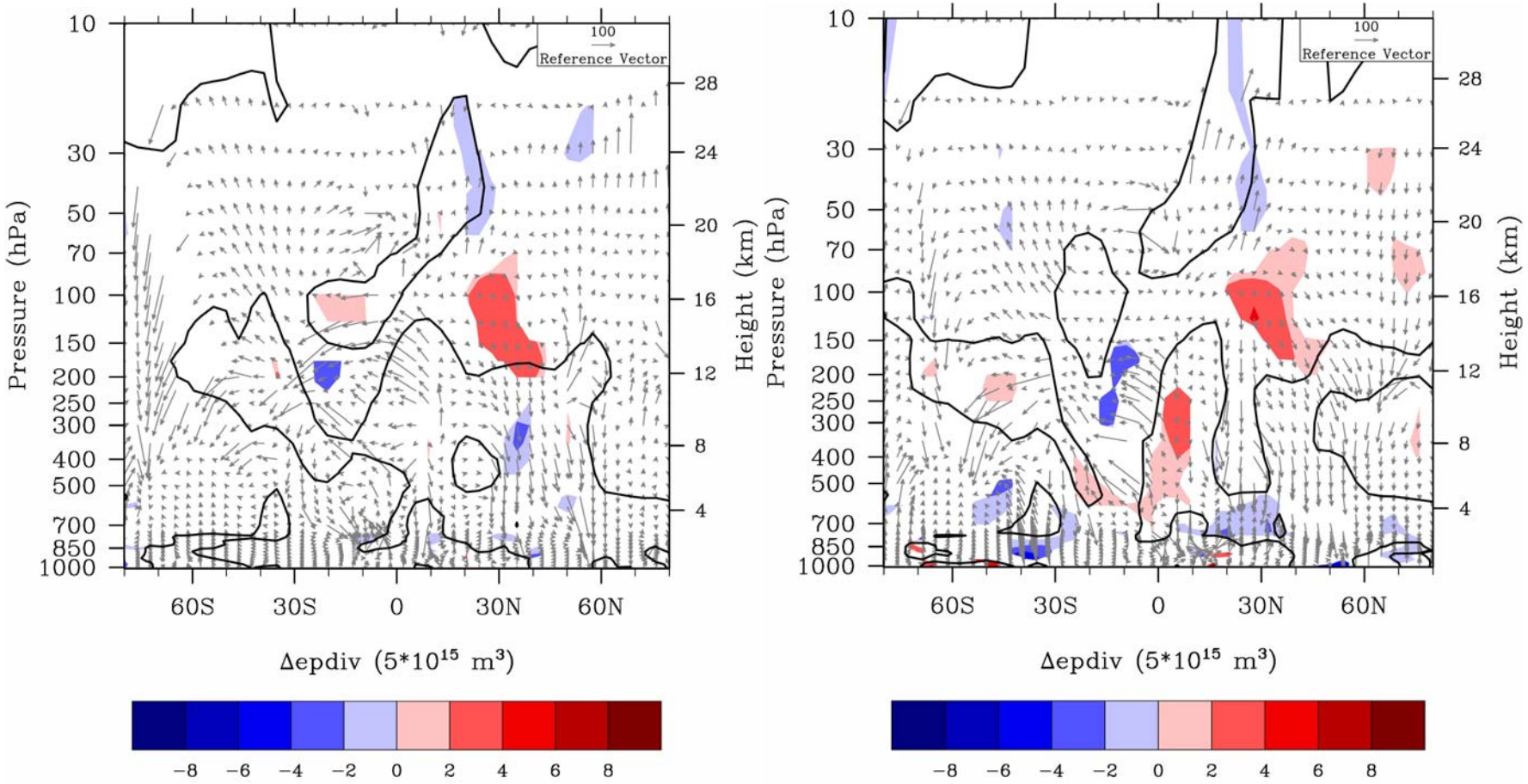
Δepdiv (5*10¹⁵ m³)
−8 −6 −4 −2 0 2 4 6 8

JJA: waves 2 & 3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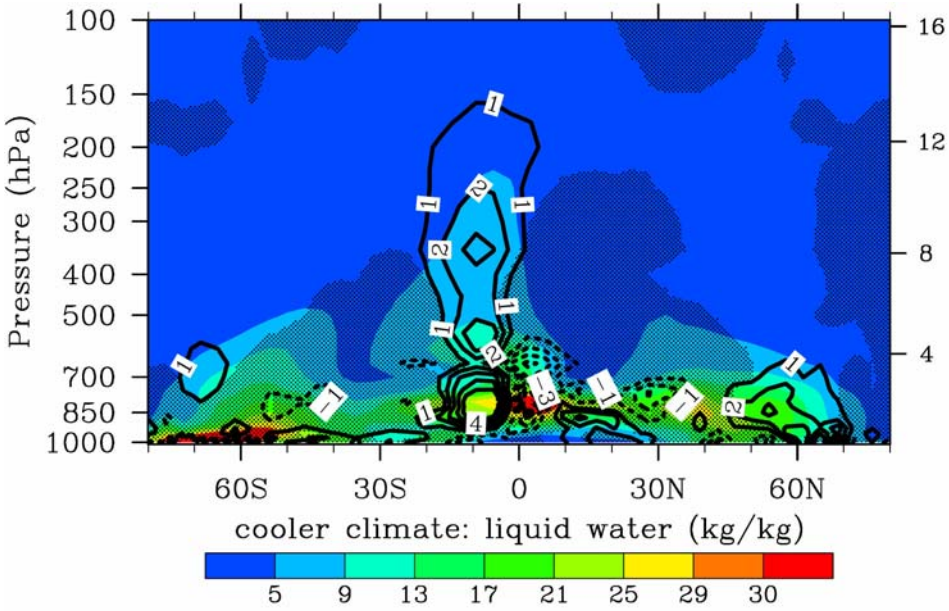
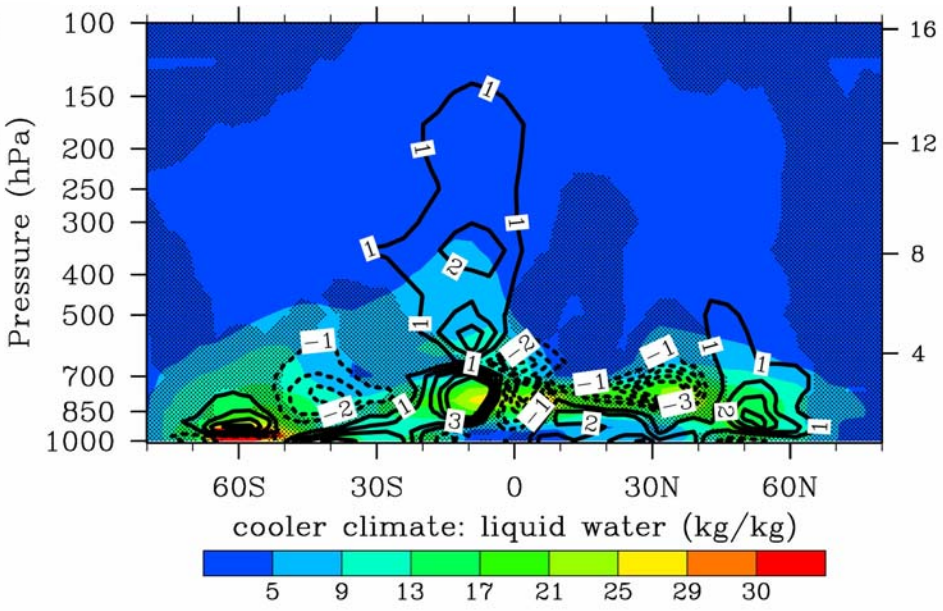
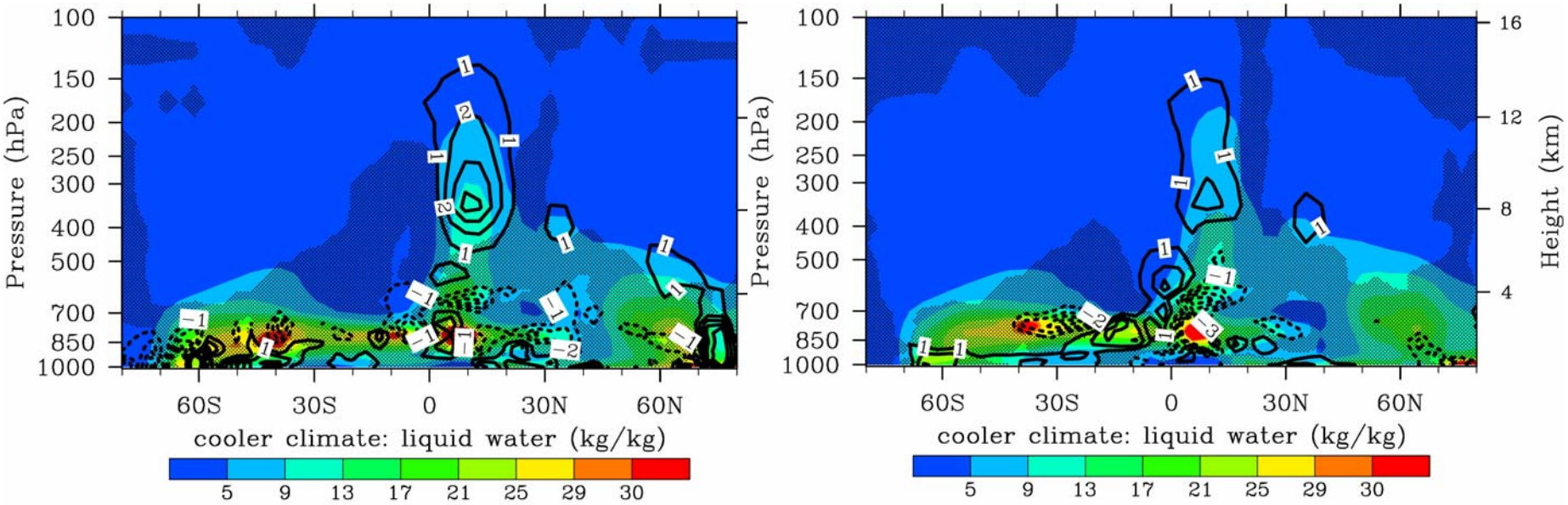
Δepdiv (5*10^15 m^3)
−8 −6 −4 −2 0 2 4 6 8

DJF: liquid water

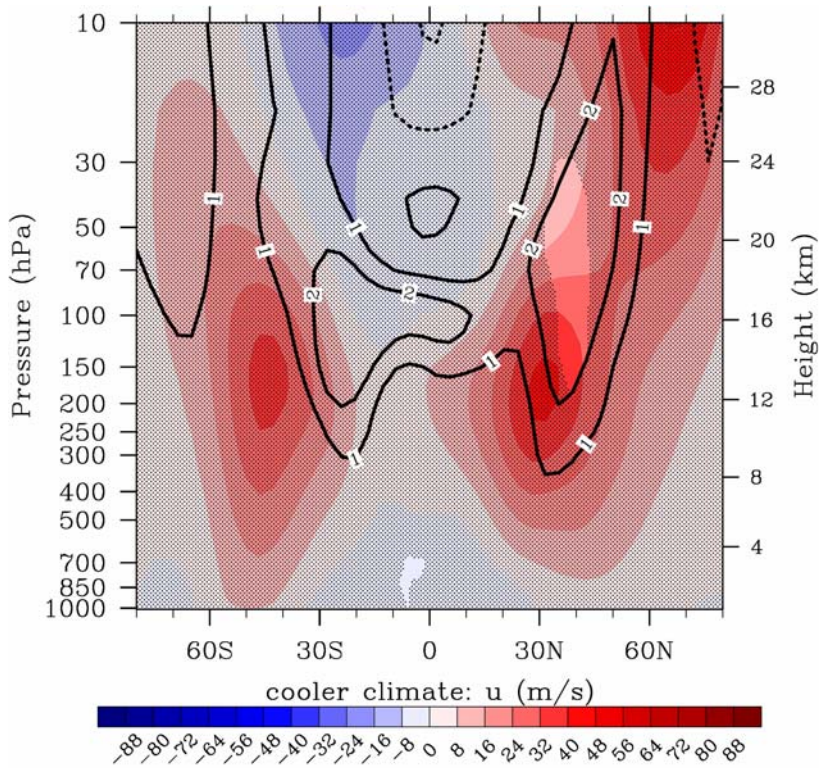




JJA: liquid water



DJF: u


Pressure (hPa)
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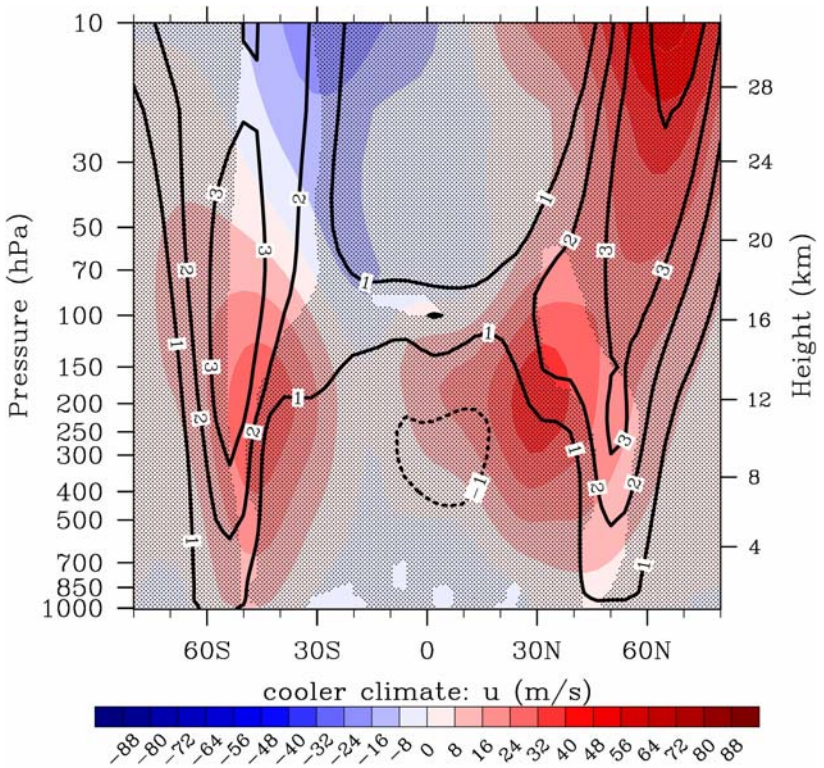
cooler climate: u (m/s)


Pressure (hPa)
Height (km)
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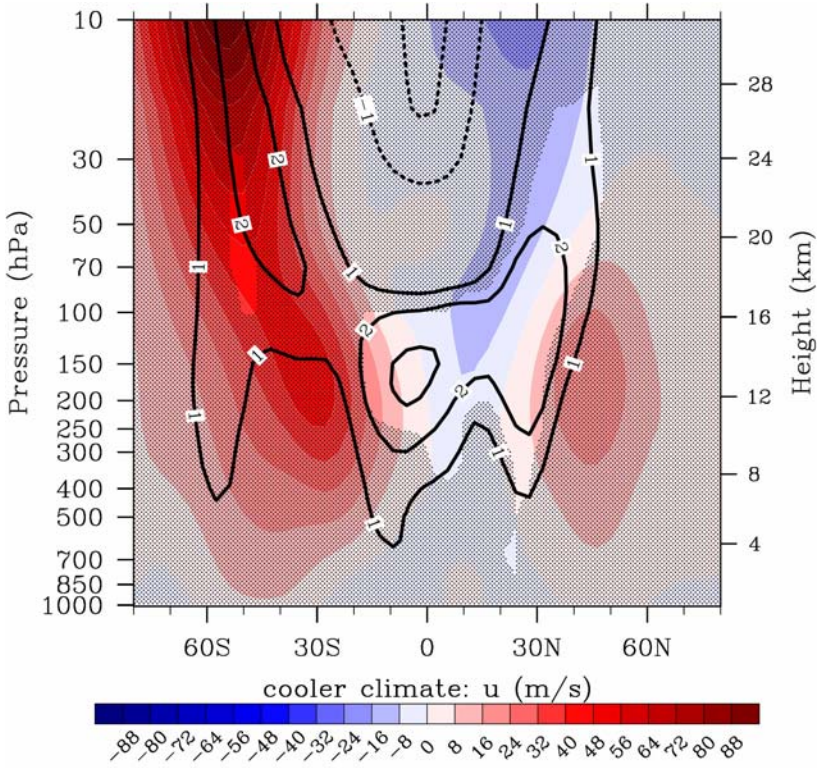
cooler climate: u (m/s)

JJA: u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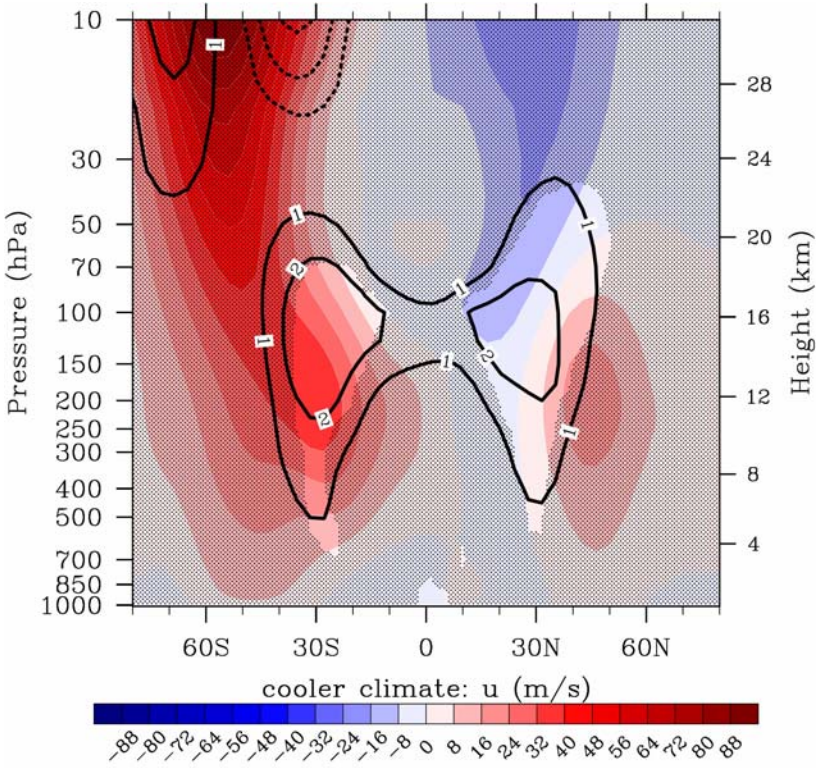
cooler climate: u (m/s)
−88 −80 −72 −64 −56 −48 −40 −32 −24 −16 −8 0 8 16 24 32 40 48 56 64 72 80 88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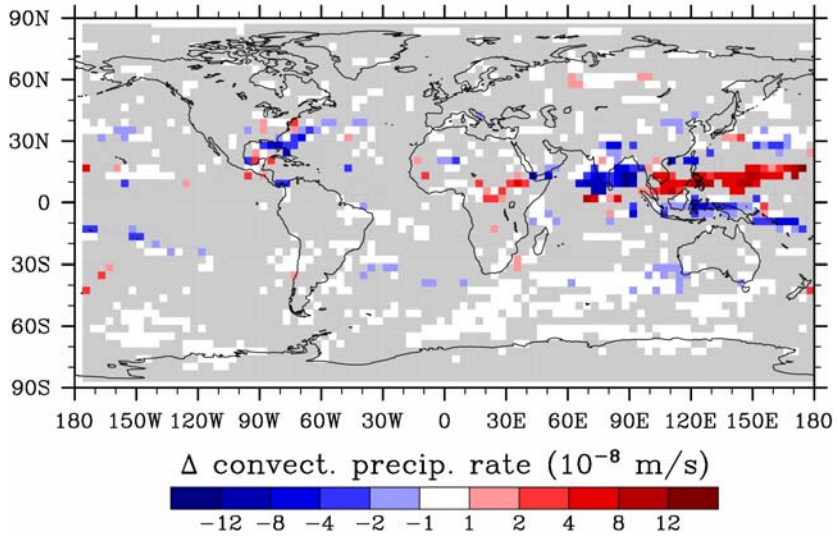
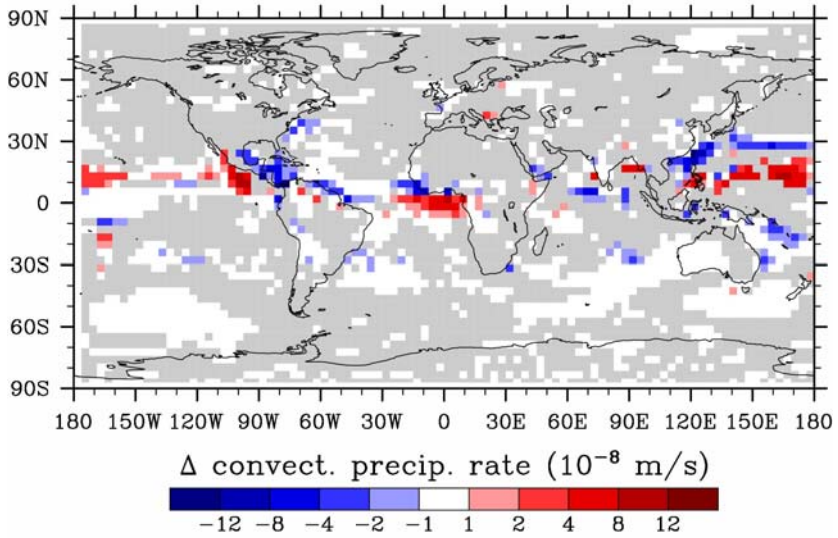
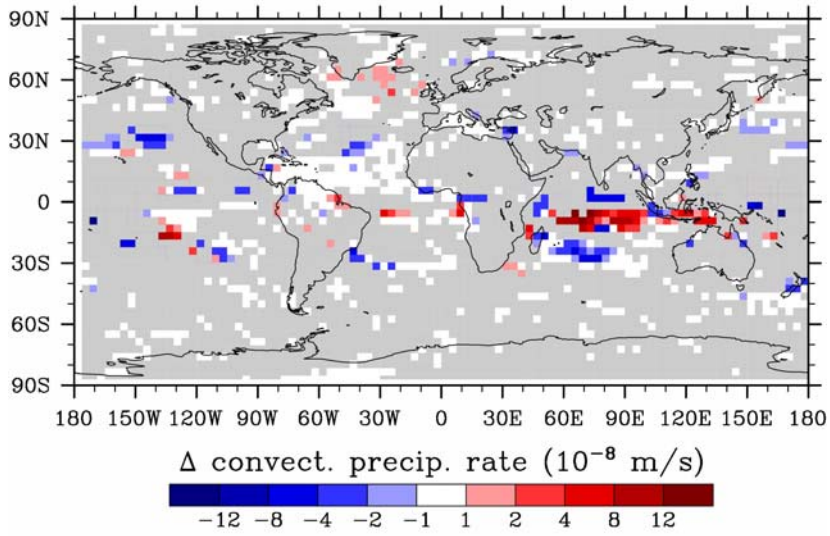
cooler climate: u (m/s)
−88 −80 −72 −64 −56 −48 −40 −32 −24 −16 −8 0 8 16 24 32 40 48 56 64 72 80 88

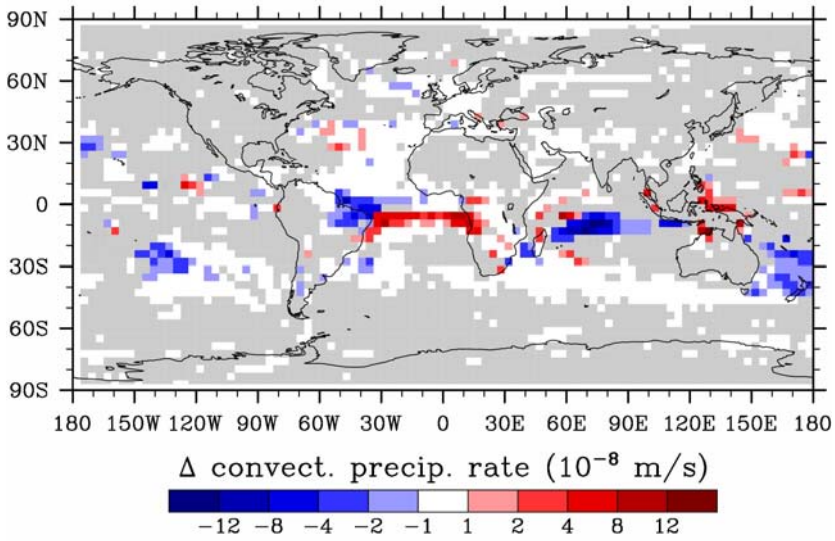
JJA: convective rain rate





DJF: convective rain rate





Annual mean: T